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Pennsylvania and the ICE AGE

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TOPOGRAPHIC AND GEOLOGIC SURVEY
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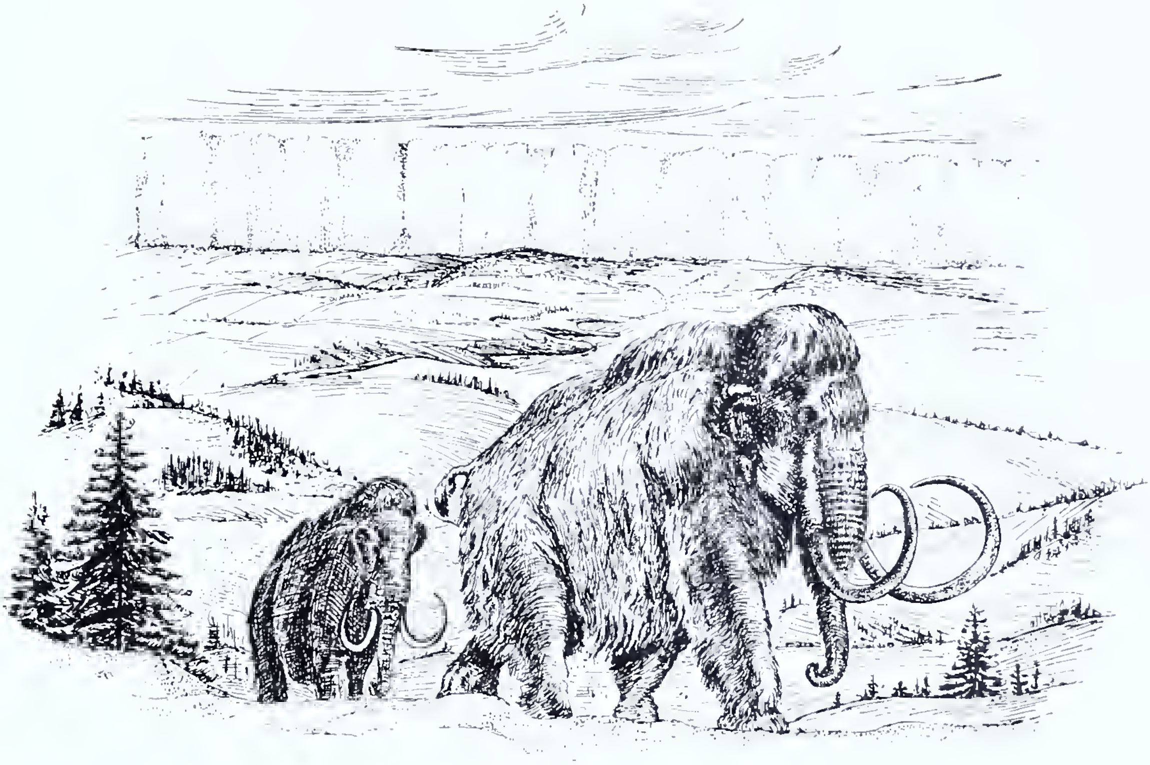

THE WOOLY MAMMOTH—A PENNSYLVANIA RESIDENT DURING THE ICE AGE

PENNSYLVANIA
AND THE
ICE AGE

by Vincent C. Shepps

Pen and ink sketches by Albert Van Olden

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LAKE ERIE—A PRODUCT OF GLACIATION

PENNSYLVANIA AND THE ICE AGE

Have you heard the story of the Ice Age, a time when great sheets of ice blanketed the northern half of North America? Perhaps it seems unbelievable that half of our continent was once buried beneath thousands of feet of ice. But such was the case as shown by scientific studies by geologists. Moreover, it is known that the continent was covered with ice not once during the Ice Age, but as many as four times. This booklet will describe these glaciations as they affected North America in general and in more detail as to how they changed Pennsylvania.

The Ice Age, known scientifically as the Pleistocene Epoch, began just before the dawn of recorded history approximately one-half million years ago. The end of the Ice Age is as yet a mystery, for some say it has ended while others maintain that we are still within it. If it is still continuing, as seems to be the case, the story of the Ice Age is one which, in part, is our own story and one with which we will want to be familiar.

We know with certainty that ice sheets of the past moved ponderously out of the Canadian north and invaded the United States, moving as far south as the Ohio River. The effects of these glaciations have had significant impact on the historic and economic development of the United States. For example, the Great Lakes have played a major role in determining political boundaries, in the economic development of the regions, and in the transportation and urban development in the area. Yet these lakes did not exist prior to the glaciation of the Ice Age.

GLACIERS

Investigations into the past have shown that glaciers existed for only a relatively few years of the earth's four billion or more years of existence. Today's glaciers are being studied by scientists from many countries. Research in Antarctica and Greenland is often reported in newspapers and magazines, but less well known studies are going on at many other glacier sites.

Why study present glaciers? Like many scientific studies, glacier study may seem to have no obvious purpose. But it is through such studies that we obtain the clues needed to properly interpret events of the past. The more we know about the present, the better we are able to evaluate the past and predict the future.

From studies of many glaciers we have learned, for example, how glaciers form, how they move, how they erode, and what happens when they melt away and disappear. We know much about the deposits of material they leave behind when they are gone. Unfortunately we cannot bring a glacier to our doorstep so that we may see what it is and what it does. From our studies of where and how they occur, and what material they leave behind, we can describe these things so that the reader may be able to picture in his mind a glacier from its birth to death.

WHAT IS A GLACIER?

Most people have seen pictures of glaciers and know that they are made of ice. But what more do we know about them? How do they form? Suppose we picture a high mountain with broad, deep valleys cut into its side. All winter long, snow falls on the mountain and into the valleys until a considerable depth of snow has piled up. This happens every year in many parts of the country, but glaciers seldom form. Why not? Simple. The snow in the valley disappears in the summer heat. This is the first clue to how and where glaciers form. In northern latitudes and in areas of high elevation, the snow does not completely melt away in the summer. Perhaps 100 feet of snow falls and 90 feet of snow melts away. When winter comes again there is already 10 feet of snow from the previous winter. It is not hard to see that through the years the snow will accumulate in great quantities.

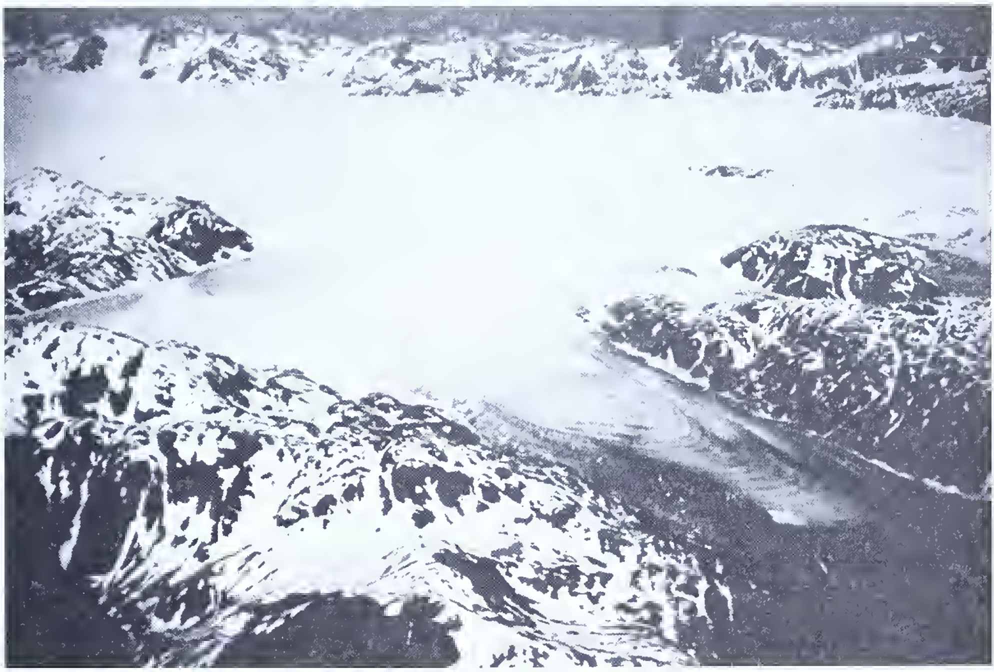

Figure 1. A snowfield in a high mountain area in Alaska. Valley glaciers leading down the sides of the mountain have their source in this snowfield where snow continually accumulates and, through pressure, is changed into glacial ice.

The snow turns to ice as more and more snow is piled on top. Snow under pressure first turns to ice granules called *firn,* and then with increasing pressure turns to solid, blue *glacial ice.* It is possible to see an example of the transition from snow to firn to ice in any area where snow falls. After the next snowfall, watch what happens to the snow. After a few days or so, the snow flakes will have turned to ice granules, particularly if the weather becomes warmer. After a longer time small patches of ice will appear. When snow is disappearing, the last remnants are nearly always ice. This happens in our climate as a result of temperature rather than pressure, but the end results are the same.

Suppose an area has accumulated a thickness of 400 feet of glacial ice, is this now a glacier? The answer is no. A mass of ice must be moving or must have moved in the past to be called a glacier. If it has never moved it is called a *snowfield.*

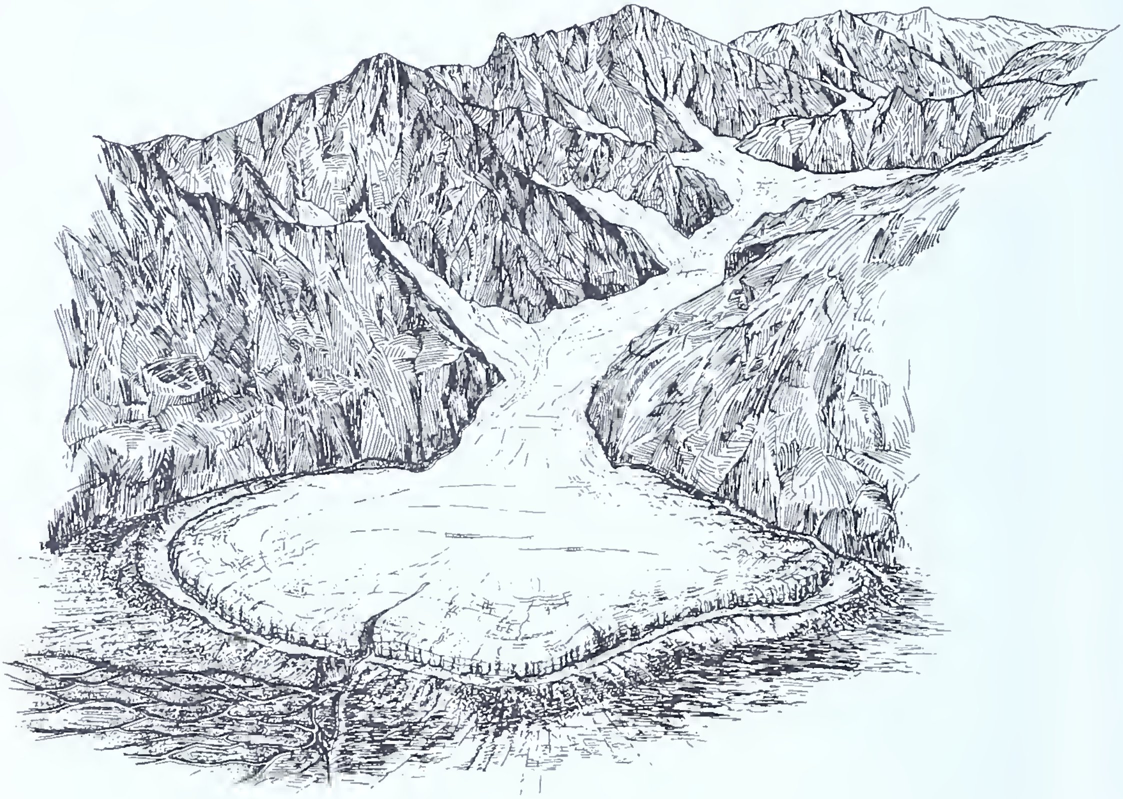

Figure 2. A valley glacier and a piedmont glacier. When a valley glacier moves out over a broad, flat area at the base of the mountain, it becomes a piedmont glacier. In many areas, piedmont glaciers become quite large where they are built from a series of valley glaciers which join in the flat area at the base of the mountain.

Movement begins whenever the ice piles up to a depth such that its weight is great enough to overcome the friction of the floor on which it is resting. Since the ice accumulation is usually greatest near the top of the mountain, the ice moves out of this area and flows down the valleys on the mountain side. Movement of the ice is similar to movement of water in a stream, though the ice moves at a much slower rate. Glaciers continue to flow as long as snow is being added at the head of the glacier high up on the mountain. The faster snow is added, the faster the glacier will move. If snowfall ceases or slows considerably, the glacier will slow down or stop and melt away. Most present-day glaciers are moving very slowly, or have stopped and are melting away.

Two major types of glaciers exist. These are *mountain glaciers* (also called *valley glaciers*) and *continental glaciers* or *ice caps.* Valley glaciers are those which are flowing down valleys in mountainous areas. The direction in which they move is controlled by the shape of the valley in which they are flowing. Special types of valley glaciers, known as *piedmont glaciers,* are formed when a valley glacier leaves the valley in which it is flowing and flows out over a broad surface when it reaches the base of the mountain.

Continental glaciers (Ice Caps) cover large areas comparable to a flood of water; the ice of a continental glacier flows over both hills and valleys. Glaciers in Greenland and Antarctia are the only ice caps existing today. The great glaciers of the Ice Age were mostly ice caps although many more valley glaciers existed then than exist today. Ice caps, like valley glaciers, also move, but in a different way. Since they occur on relatively flat or undulating land, they do not move down the slope of the land, but instead move outward in all directions from the part of the ice cap which has the highest elevation. This is also the place where the ice is usually the thickest. This type of movement can be compared to that which happens when pancake batter is poured onto a griddle. The batter moves outward in all directions while the pancake becomes thinner. If more batter is poured onto the center of the pancake, the edges will again expand while the center flattens out.

THE MOVING GLACIER

Returning to the valley glacier as a body of ice creeping slowly down a valley, let us consider what is happening down inside the glacier and at the base of the ice. We know that valleys such as Yosemite in California which have been glaciated have an entirely different appearance from valleys which have been cut by streams. The glaciated valleys are usually deeper, have steeper walls, and have a flatter bottom than a stream valley. It would appear that the ice, in moving through the valley for a number of years has performed a great feat of erosion in wearing away the valley. Such is indeed the case. In spite of their slow movement, and the fact that ice is much softer than rock, glaciers are powerful eroding agents. How can this be? To give an answer, let's consider a clean ice cube fresh out of the tray.

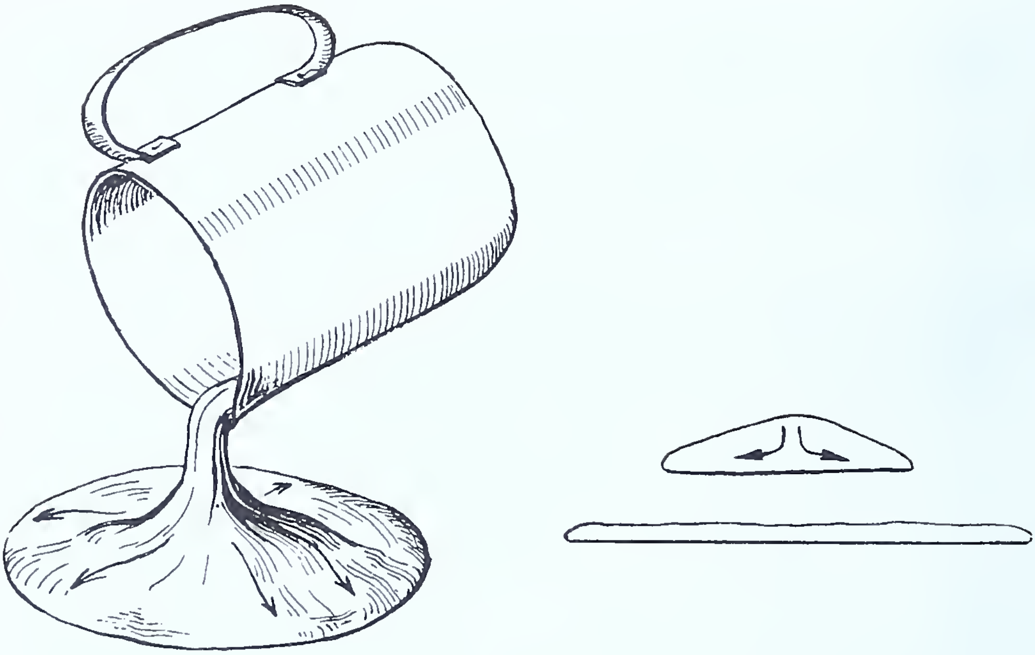

Figure 3. Movement of ice within a continental glacier is similar to movement within a pancake. Thicker batter in the center of the pancake exerts more pressure downward than is exerted in areas where the batter is thinner. Batter in the center is squeezed outward in all directions towards areas of less pressure. The edges of the pancake move outward until the pressure moving them equals the opposing pressure created by the viscosity of the batter and the friction of the surface across which the batter is moving.

If you slide this across the sink, very little would result other than cold fingers and melted ice. Instead, press the ice first into sand and then repeat the experiment sliding the ice across the sink. The sink would then be scratched. True, the ice did not scratch the sink, but the sand grains sticking to the ice acted as a tool with which to do the scratching.

In glaciers, rocks of all sizes are frozen into the bottom of the ice or are pushed along by the ice. These are used as cutting tools just the same as the sand in the experiment. As movement progresses, the broken rock is gradually mashed into smaller and smaller pieces so that the bottom of the ice becomes filled with rock debris of all different kinds and sizes. Because the bottom of the ice is moving across an uneven surface, it is broken up and squeezed. This action moves rock fragments higher and higher into the ice so that the lower part of the glacier gradually becomes filled with broken and crushed rock debris.

Picture in your mind what might happen to all of this rock debris when the glacier melts away.

THE ICE MELTS

Melting of a glacier occurs even when the ice is moving. The top surface melts continually during warm periods. The water produced by melting, called *meltwater*, may either run off the ice, or may sink into the ice and refreeze. Most melting occurs along the edge of the ice sheet. If the front edge of the ice is melting away at the same speed as the glacier is advancing, the ice edge will remain at one place. If melting is faster than the movement of the glacier, the front edge will be retreating back toward the area of snow accumulation even though the glacier as a whole is moving forward.

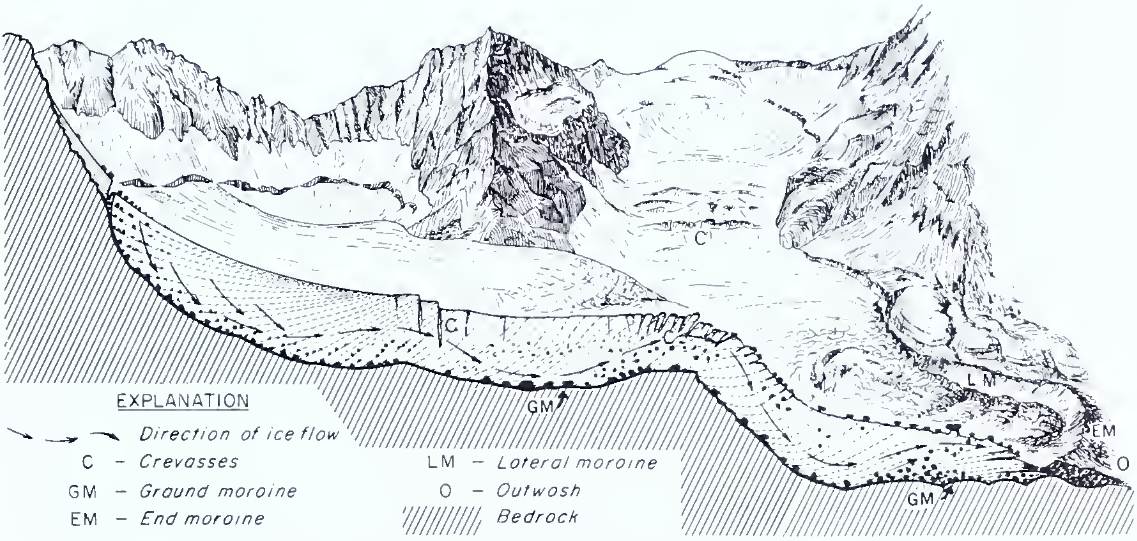

Figure 4. View and cross section of a typical valley glacier. Cross section (in the foreground) shows the internal structure of the moving ice mass. Rock debris is concentrated along the base of the ice but is found also at higher levels where it has been carried upward along shear planes (dashed lines). Near the end of the glacier, some of this material is exposed as the surface of the ice is lowered by melting. The debris is piled up in the end moraine as material is dropped at the melting end of the glacier. Because the glacier is moving forward, it continually brings new material to be added to the end and the lateral moraines. Crevassing of the ice occurs at the end of the glacier and at positions along its course where the ice rises to flow over irregularities in the valley bottom. (Modified from R. Streiff-Becker, 1943).

As the ice melts, the rock fragments are freed and drop out of the ice where they are piled up in place, or are picked up and carried away by meltwater streams. Melting and water activity at the front of a glacier is always great, and many streams flow away from the front of the ice. Because rock fragments are abundant and are easily picked up by running water, the streams flowing from the ice are usually clogged with sediments of all kinds. This is true whether the glacier is a mountain type or an ice cap. If we were to visit the front edge of a glacier we would see large piles of crushed rock all around the edge. We would see the streams flowing from the ice so filled with ground rock that the water looks like milk. In front of the glacier would be a broad, flat plain, called an *outwash plain,* over which the streams were flowing. If this plain is confined within a valley, it is called a *valley train.* The plain is built up of rock debris which the streams picked up when they were flowing swiftly, but which they dropped when they slowed down after leaving the ice front. Blocks of ice, broken off from the edge of the glacier, would be seen sticking out of the outwash plain. At places we could see pits in the gravel plain where the ice blocks were lodged and then melted away leaving a hole. Because of their shape, these pits have been called *kettles.*

All of the rock debris deposited by the glacier is called *drift.* Drift includes even the material carried away by meltwaters and deposited later. Some of the debris is dropped directly onto the ground when the ice melts, without being disturbed by running water. This material is called *till* or *moraine.* The characteristic of this material is that it consists of fragments of all different sizes. The pile or ridge of material built up around the edge of the glacier is called the *end* or *terminal moraine.* Moraines also form along the sides of valley glaciers between the ice and the valley wall. These are called *lateral moraines.*

With the final melting of the glacier, all of the debris pushed along under the ice or carried in the lower layers of the ice is left stranded as a blanket over the landscape. Most of this material is not acted upon by streams and is therefore till. This blanket of till is known as the *ground moraine.*

If there is a change in climate or a decrease in snowfall, a glacier will cease its movement and come to a standstill. At that time the glacier becomes no more than a large mass of melting ice and the load it is carrying is deposited in a different manner. The end and lateral moraines are no longer formed although deposits are still being added to the outwash plain. Think of this large mass of ice and try to imagine what is happening during melting. Melting occurs everywhere over the surface of the ice and down along the walls of the crevasses or deep cracks which exist in any glacier. Meltwaters are abundant and flow in whatever direction gravity leads them. Some flow over the surface

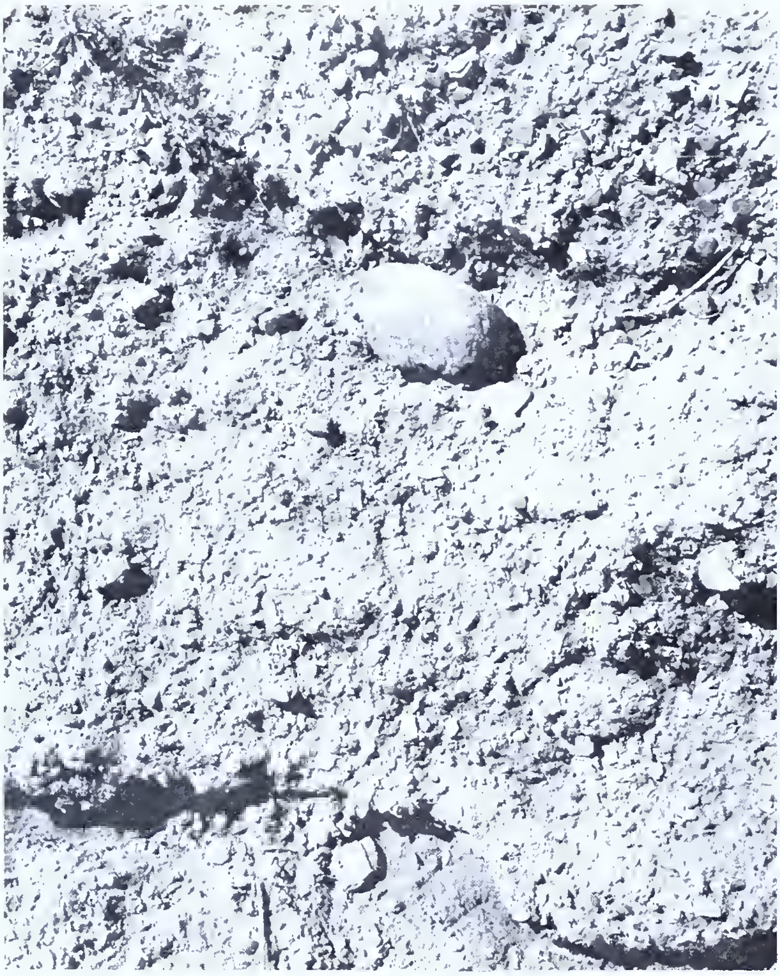

Figure 5. Till. This material, also called moraine, is deposited directly by a glacier. It has not been acted upon by water and is not sorted, so that it contains a mixture of rock fragments of all sizes ranging from clay to boulders. The pebble in this picture measures three inches across. Note that the material is dense, is not porous, and is not bedded, differing in these ways from stream-laid materials.

of the ice, but most flow along the crevasses which are slowly being widened as they are melted by running water. The melt-waters flowing in the crevasses and the streams flowing away from the edge of the ice are carrying rock debris. Much of the debris is carried away from the ice or builds up new areas of outwash plain as the front of the ice retreats by melting. Melt-water streams can carry great quantities of material and are usually capable of picking up fragments of quite large size. The material carried by these rampaging streams is dropped and deposited whenever the rate at which the stream is flowing decreases.

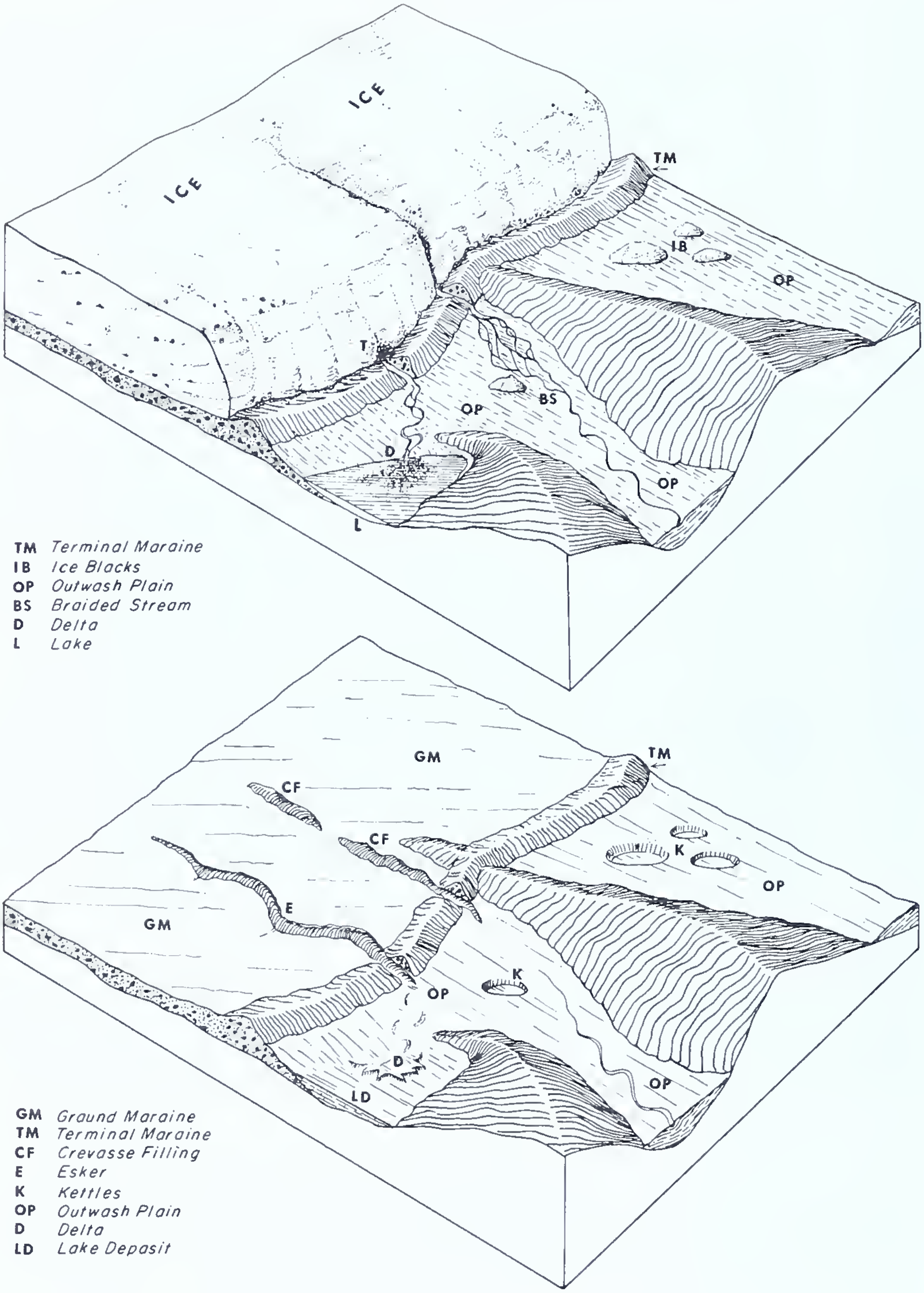

Figure 6. Block diagrams showing an area undergoing glaciation by a continental ice sheet and the resulting topography and deposits after the ice has melted away.

This material is different from till because it has been moved by a stream. The stream "sorts" the material. Till, you will recall, consists of fragments of rock of many different sizes—boulders, pebbles, sand, silt, and clay all mixed together. Stream deposited material, called fluvial material, usually consists of only a few of these sizes such as sand and pebbles. Stream deposits, moreover, are bedded. That is, the sediments are deposited in layers; till is not bedded. Clay and silt are dropped from a stream only when the stream is moving very slowly or comes to a standstill as it does when it enters a lake.

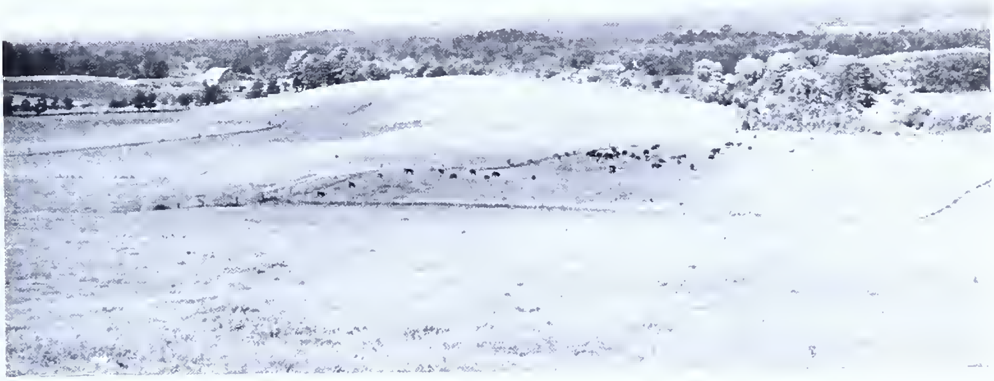

Figure 7. A group of kames. These mounds are composed of sand and gravel which was deposited by meltwater activity during the Wisconsin glaciation in northwestern Pennsylvania. Kame group is located just east of Route 19 approximately ½ mile north of Waterford, Erie County, Pennsylvania.

The deposits of the meltwaters remain scattered over the landscape after the ice has disappeared. Here and there a mound of sand and gravel juts up above the land surface. Such mounds are called *kames;* a group of kames is called a *kame field.* Waters sometimes find an outlet from the ice by flowing through a tunnel in the ice or at the base of the glacier. Sand and gravel are deposited all along the tunnel floor, which when the ice disappears, form a winding ridge across the land surface that often looks like an abandoned railroad embankment. This ridge is called an *esker.*

Because so much water is present when the ice is melting, lakes are common. Small lakes form in kettle holes and lakes of

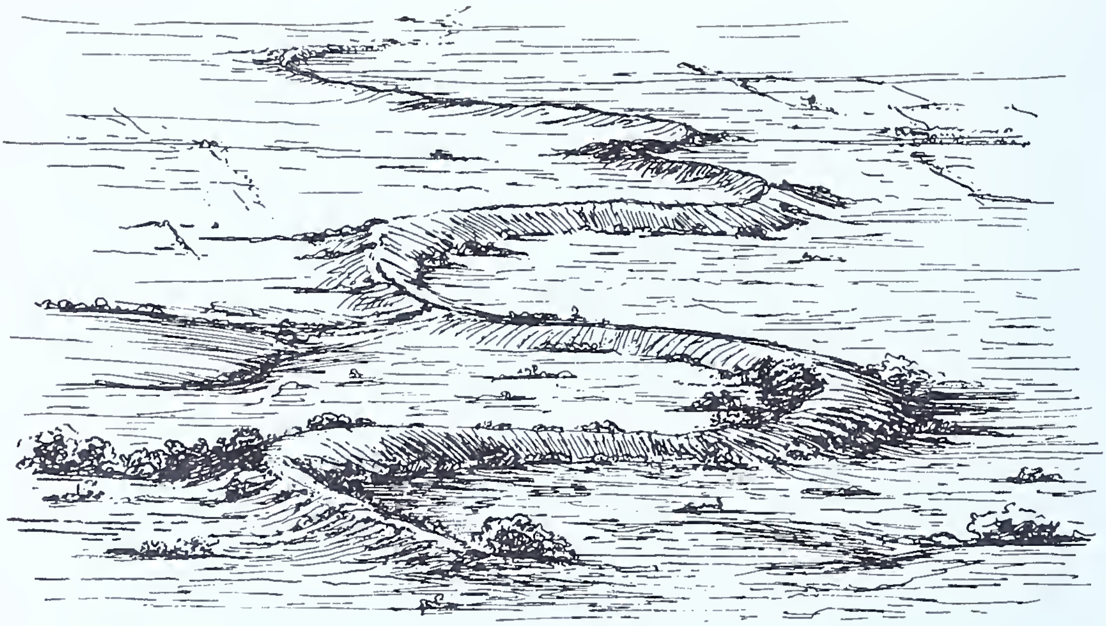

Figure 8. An esker. A winding ridge of stratified (layered) or crudely stratifed sand and gravel. These are commonly found associated with kames and are thought to have formed in a tunnel in or beneath the ice of a glacier. Because of their winding nature and their association with kames, they have at times been called "serpent kames."

many sizes form where the path of a stream is blocked by debris or ice. When a stream flows into one of these lakes, its movement is slowed down or stopped. It can no longer carry the rock fragments it carried when it was moving swiftly so that it drops this material upon entering the lake. The largest fragments are dropped first, and gradually, as the stream slows more and more, finer and finer materials are dropped. The coarse materials spread out as a fan on the lake bottom to form a delta at the place where the stream enters the lake. Finer silts and clays spread throughout the lake and gradually build up blanket-like layers over the entire bottom of the lake. If enough sediment is brought into the lake, it will eventually fill to the surface and the lake will be no more. Toward the last phases of this filling, when the water is very shallow, swamp vegetation will spread out over the surface so that the last filling of the lake will be dead and dying vegetation which builds up in layers to form peat.

We have now carried a glacier through its life cycle from birth to death and have learned about its power to erode and deposit. When the glacier is gone it leaves behind two major types of material—till, which is unsorted so that it contains rock fragments of many sizes, and meltwater deposits, called *glaciofluvial deposits*, which are sorted so that they contain fragments of only one or two sizes, usually sand and gravel. Because of the way they are deposited, the piles or blankets of rock fragments have been named. Till is piled up as end, lateral, or ground moraine. Glaciofluvial deposits are laid down as mounds (kames), ridges (eskers), or as a flat-topped plain (outwash plain). Where lakes were present the material may have been deposited as a delta or as layered lake sediments.

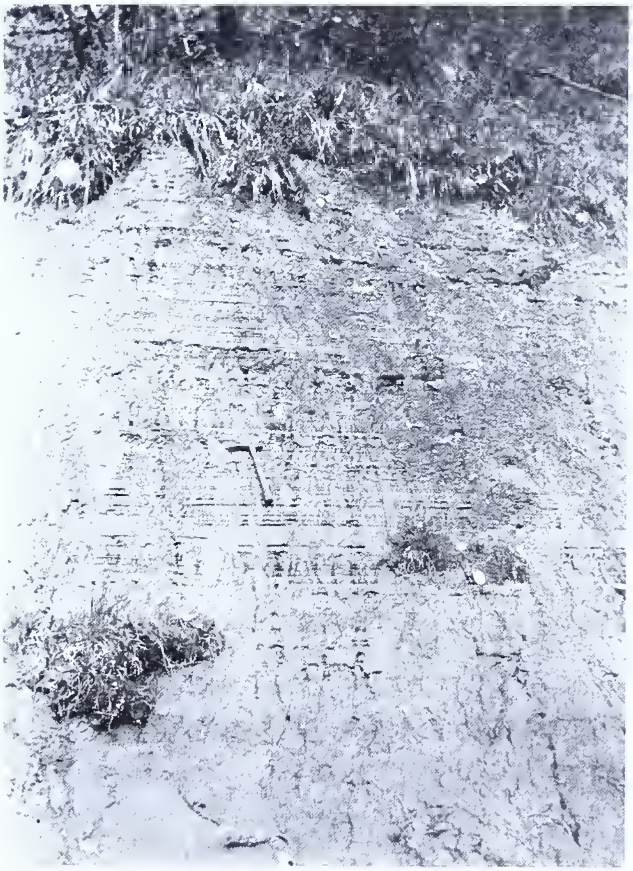

Figure 9. Lake sediments deposited in glacial Lake Cowanesque, an Ice Age lake in Tioga County. The thin, uniform layers are typical of lake sediments. Commonly these are laid down in alternate light, coarse-grained layers and dark, fine-grained layers called varves. Varves represent seasonal deposits, the light layers being deposited in spring and summer and the dark layers in fall and winter. By counting the number of varves in a section of lake deposits, it is possible to tell how many years the lake existed.

THE ICE AGE AND GLACIERS OF THE PAST

Just as scientists have studied modern glaciers to see how they form different kinds of deposits, they have studied the deposits to learn what they have to tell about the glacier. If a glacier has moved over an area, but has since melted away, it leaves its deposits behind. By studying the deposits it is possible to picture what the glacier looked like. For example, suppose a great ice sheet moved into Pennsylvania and then melted away until the front edge of the glacier had retreated into Canada. Suppose also that many years later the same ice mass, still existing in Canada, began to build up again and once more moved into Pennsylvania, but not as far south as the first one had moved. How would we know now, many years after the ice had completely melted, that these events had occurred? The first advance of the ice would have left behind an end moraine to mark the position of its greatest advance. The second advance would have done the same, but its end moraine would be at some position behind the end moraine of the first advance. Each advance would also have left behind a ground moraine blanketing the landscape. But because the second advance moved over the ground moraine of the first advance, we might expect to find, in places, one ground moraine piled on top of another. The one on top would be the youngest; the one beneath would be older.

Just such things have been found not only in Pennsylvania, but also throughout northern United States and Canada. By studying all of the different glacial deposits in these areas, and recording them on maps, the scientists have been able to learn the history of the Ice Age. The story is not complete, for not all areas have been studied, and some of the deposits of the earliest ice advances have been eroded away through the years.

The history of these advances as we know it is as follows: For some reason, still unknown, snowfall began to increase in areas of northern Canada about a half million years ago. Through the years, ice accumulated to a great thickness so that a glacier perhaps more than a mile thick was formed.

As the ice built up, the glacier began to move outward in all directions like the pancake batter we talked about earlier. Snowfall continued and the ice was built up to so great a thickness that the spreading out of the glacier pushed it south into the United States. This first build-up of ice and the first glaciation of the United States is known as the Nebraskan glaciation because the deposits of this advance are best preserved in the state of Nebraska. Because a great amount of time has passed since

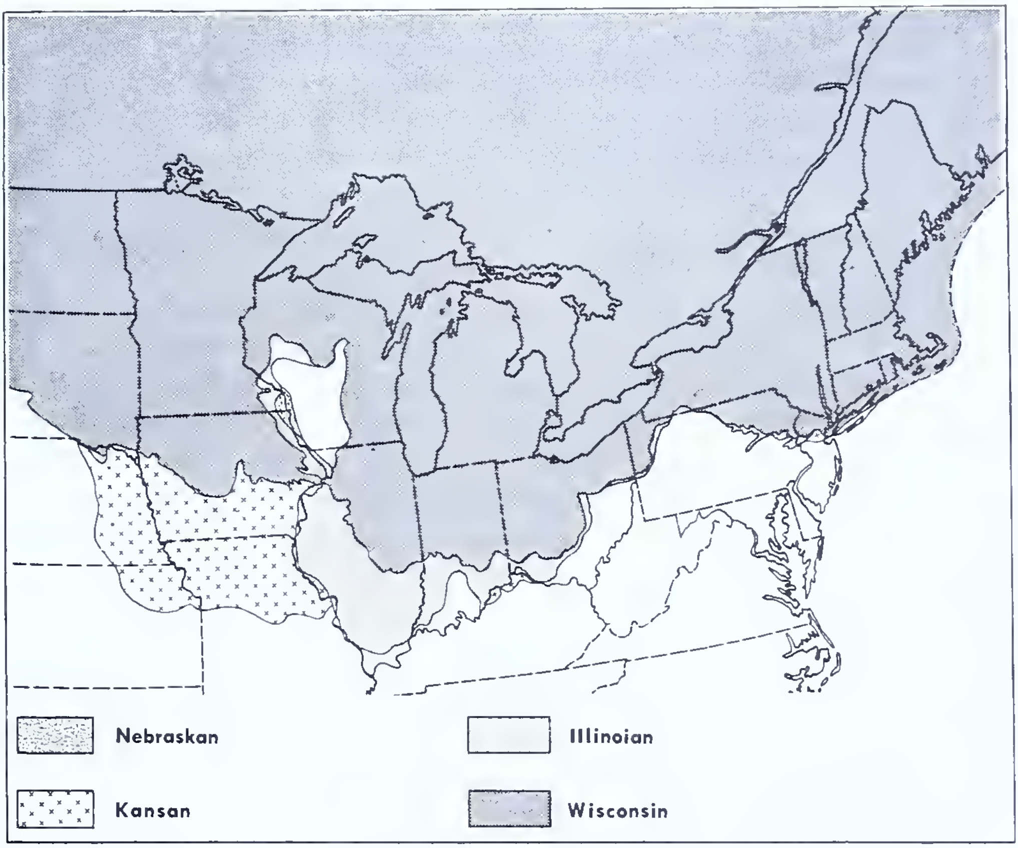

Figure 10. Areas of eastern North America covered by deposits of the four major ice invasions of the Ice Age. Deposits of the first advance, the Nebraskan, are covered except in a small area in Minnesota, Iowa, and Wisconsin by deposits of the later advances. Deposits of the next advances, the Kansan and Illinoian, are likewise nearly everywhere covered by deposits of the last ice advance, the Wisconsin.

the Nebraskan glaciation, and because most of its deposits have been covered by later advances, we know little of the details of the earliest period of glaciation.

After many years, the climate changed, snowfall ceased or slowed down, and the great Nebraskan ice sheet melted away. After a long warm period, snowfall increased once more as the climate became cooler, and a new ice sheet formed which once again spread into the United States. This second great advance is known as the Kansan glaciation. After a period of time, this ice sheet disappeared much in the same way as the Nebraskan ice sheet vanished, and a period of warmer climate prevailed for many years more. Then, for a third time, ice began to accumulate and another glaciation known as the Illinoian glaciation sent ice sheets into northern United States. Still another period of warming followed and melted away this ice sheet.

Finally, about 70,000 years ago, the fourth and last of the great ice sheets, the Wisconsin glaciation, formed in Canada and spread southward. This ice advance covered large areas of northern United States, blanketing former glacial deposits with deposits of its own. Because this advance is the most recent one and because its deposits are at the surface and not buried under other deposits, we know most about its history.

Because of their great thickness, the pressure at the base of the ice sheets was very great. As the ice moved along with pieces of rock it had picked up, it scraped the soil off the bedrock, scoured and scratched the exposed rock, and pressed itself down into valleys, cutting them sometimes to great depths. The material picked up and carried or pushed along by the ice, later to be deposited as till or outwash, was moved in some cases for hundreds of miles. Rocks picked up in Canada were mixed with rocks picked up in New York State and these in turn were mixed with rocks picked up in Pennsylvania. In deposits of glacial materials in Pennsylvania, you will find many different kinds of rock and many types which do not occur in Pennsylvania. Igneous rocks, such as granite, that have come great distances, may be found. Pieces of copper ore, nickel ore, and even diamonds have been found in glacial deposits and none of these occur in the bedrock near where they were found in the glacial deposits. The ice, in moving south, overrode forests in some places and it is not unusual to find fossil wood mixed with the base of the till.

GLACIATION IN PENNSYLVANIA

A map presented earlier in this booklet showed the extent to which the advances of glaciers during the four great glaciations had moved into northern United States. But because we, as Pennsylvanians, are most interested in knowing the history of the Ice Age in our State, we will look in more detail at this story. Of the four major glaciations, we know that ice moved into Pennsylvania only during the last two, the Illinoian and Wisconsin advances. This does not mean that earlier ice did not reach Pennsylvania. Deposits of the earlier glaciations have not been found, but these may be very difficult to find for two reasons—1. The two earlier glaciations occurred so long ago that the deposits may have been largely removed by erosion and 2. The later ice advances may have completely covered up the earlier deposits. The Illinoian ice moved into eastern Pennsylvania from the northeast and flowed as far south as Allentown. It flowed also into northwestern Pennsylvania reaching almost to the Allegheny River. The map of Pennsylvania shows the line to which this

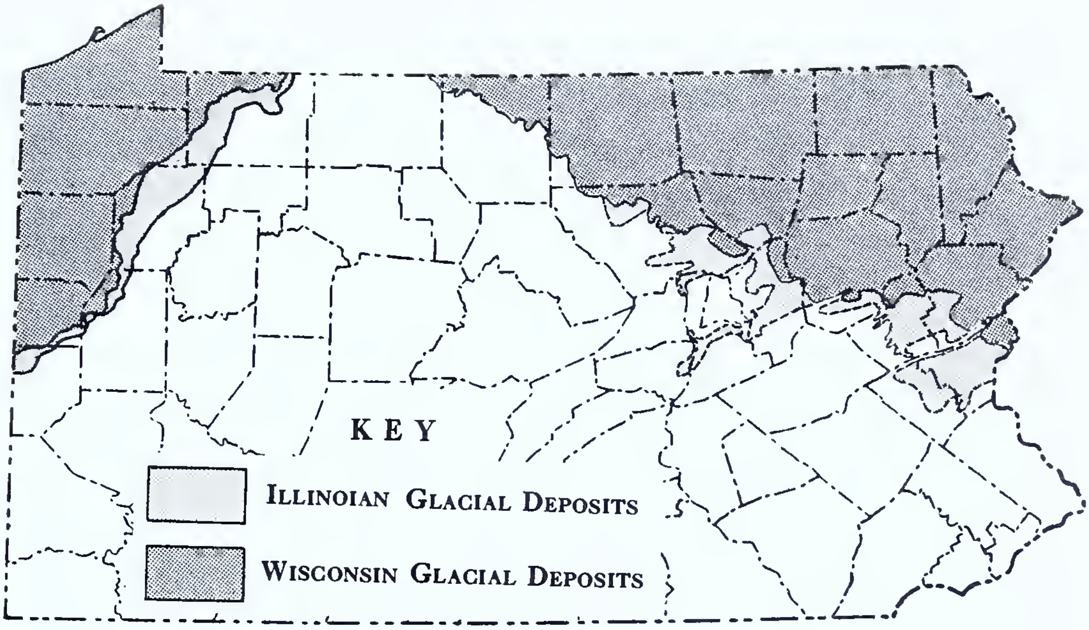

Figure 11. Areas of Pennsylvania covered by deposits of the Illinoian and Wisconsin ice advances. Illinoian deposits are at the surface only where they have not been covered by deposits of the later Wisconsin ice advances. In addition to the areas of glacial deposits shown on this map, valley train terraces exist along many of the streams which drained the front of the ice masses, such as the Susquehanna and Delaware Rivers.

glaciation moved. Because the Illinoian glaciation occurred a long time ago (more than 75,000 years ago), preceding the recent ice advance, the Wisconsin, the deposits left by the ice have been highly weathered and in many places have been eroded away. We do not know if the Illinoian ice built an end moraine, for no end moraine exists today. The only evidence we have that the ice reached some areas of the State is the presence in the plowed fields of boulders, pebbles, or cobbles of rock that must have been brought to the area from a great distance. These rounded and worn pieces of rock which are foreign to the area are called *erratics.*

The Wisconsin ice advance moved into the same areas as had been invaded by the Illinoian ice, but nearly everywhere moved a shorter distance. The map of Pennsylvania shows the outer limit of the Wisconsin glaciation. By the time the Wisconsin ice reached the United States, the ice front was no longer a straight line, but the ice had slowed down in some areas and moved faster in others so that it was advancing as a series of tongues or lobes. One lobe moved through the depression that was to become Lake Erie and pushed into eastern Ohio, spreading out into northwestern Pennsylvania. Another lobe advanced from the east and

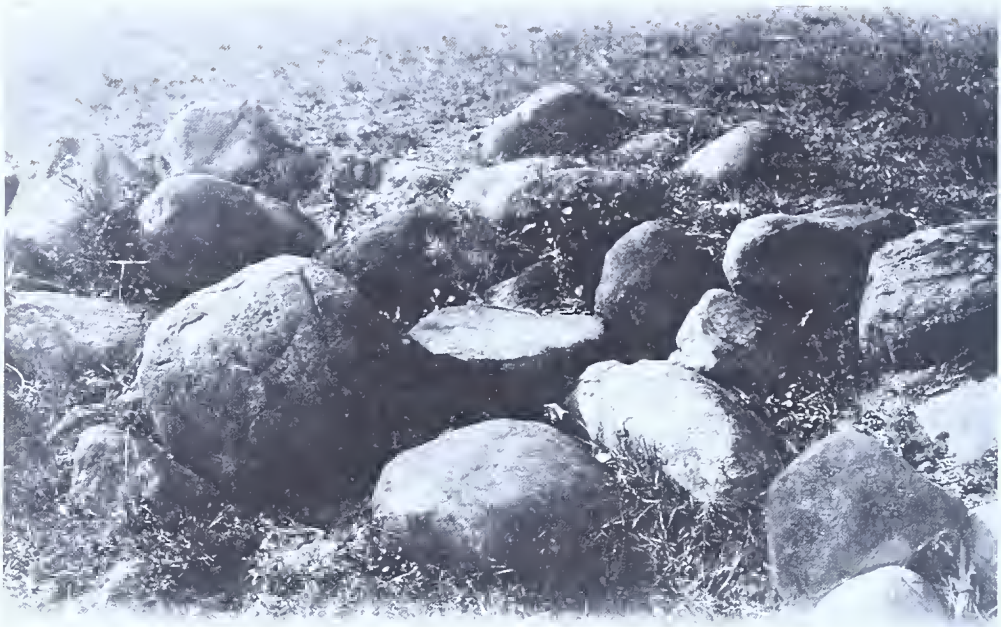

Figure 12. A group of erratics in Mercer County. These erratics are glacially carried granites and quartzites, rock types which are foreign to the area. They were picked up by ice as it moved across Canada and were carried and redeposited in Mercer County when the ice melted. In the area in which these were found, no other glacial deposits remain, so that, were it not for the presence of erratics, we would not know that the area had been glaciated.

northeast and spread out over eastern Pennsylvania. The tongues followed the paths of least resistance flowing downhill wherever possible and being slowed down locally where they met high ground. Because the ice was so thick, it moved over mountains as high as several thousand feet, but in doing so it lost some of its energy so that it was not able to move as far as ice which met less resistance. This is best seen in eastern Pennsylvania where the ice flowing in the valley far outdistanced the ice covering the mountains.

NORTHWESTERN PENNSYLVANIA

The deposits of the glaciers have been studied carefully in northwestern Pennsylvania so that the history of this area is well known. All types of glacial deposits can be found in northwestern Pennsylvania including end and ground moraine, kames, eskers, outwash, and lake deposits. If you are interested in reading more about the details of the glaciation of this area, you will find the information in a booklet called "The glacial geology of northwestern Pennsylvania" which was published by the Pennsylvania Geological Survey as Bulletin G-32. Included with the booklet is a colored wall map which shows the location of the deposits of till and outwash left behind by the glaciers.

Some of the glacial forms to be seen in northwestern Pennsylvania are among the best to be seen anywhere. The end moraine of the Wisconsin ice advance is a bold feature which has greatly influenced the scenery and the development of the area in which it occurs. The land surface in the area of the moraine is quite rolling compared to the smooth surface in adjacent parts of northwestern Pennsylvania. Small ponds and swampy depressions and knob-like mounds of sand and gravel are common in the end moraine. Figure 13 shows an area of the end moraine in Crawford County which is especially well developed. If you were to drive through the end moraine, particularly in Wayne Township, you would see immediately the difference in the land surface in the end moraine as compared to the land surface in the ground moraine in Randolph Township. The large arrows on this map and on succeeding maps show the direction in which the ice moved. The small arrows show the direction in which the meltwaters flowed away from the ice edge. The bottoms of the valleys through which the meltwaters flowed have been filled with outwash (valley train) material so that they now have a rather flat surface as shown on the map.

Figure 14 shows an area of Butler, Lawrence, and Mercer Counties in which eskers are numerous. These winding ridges are one of the best sources of sand and gravel in the area. The esker just north of Slippery Rock (#1) has been so extensively quarried for sand and gravel that it has been almost completely removed. The esker in Worth Township (#2) can be best seen along the road going north through Jacksville. In many places this feature is quite flat topped so that it looks much like an old railroad embankment.

The area in northwestern Pennsylvania which best illustrates glacial deposits is in and around Conneaut Lake in Crawford County. In this one area, most of the features produced by moving and melting ice have been formed. During the melting of the Wisconsin ice sheet, a rebuilding and readvance of the ice occurred and a tongue of ice, much like a valley glacier, came down the valley north of Conneaut Lake and spread out into the area around the lake. The edge of this tongue of ice is shown on the map by the barbed line. The barbs point toward the ice tongue. All of the features inside the line toward the lake were formed by the tongue. Features outside of the line were formed by an earlier ice sheet.

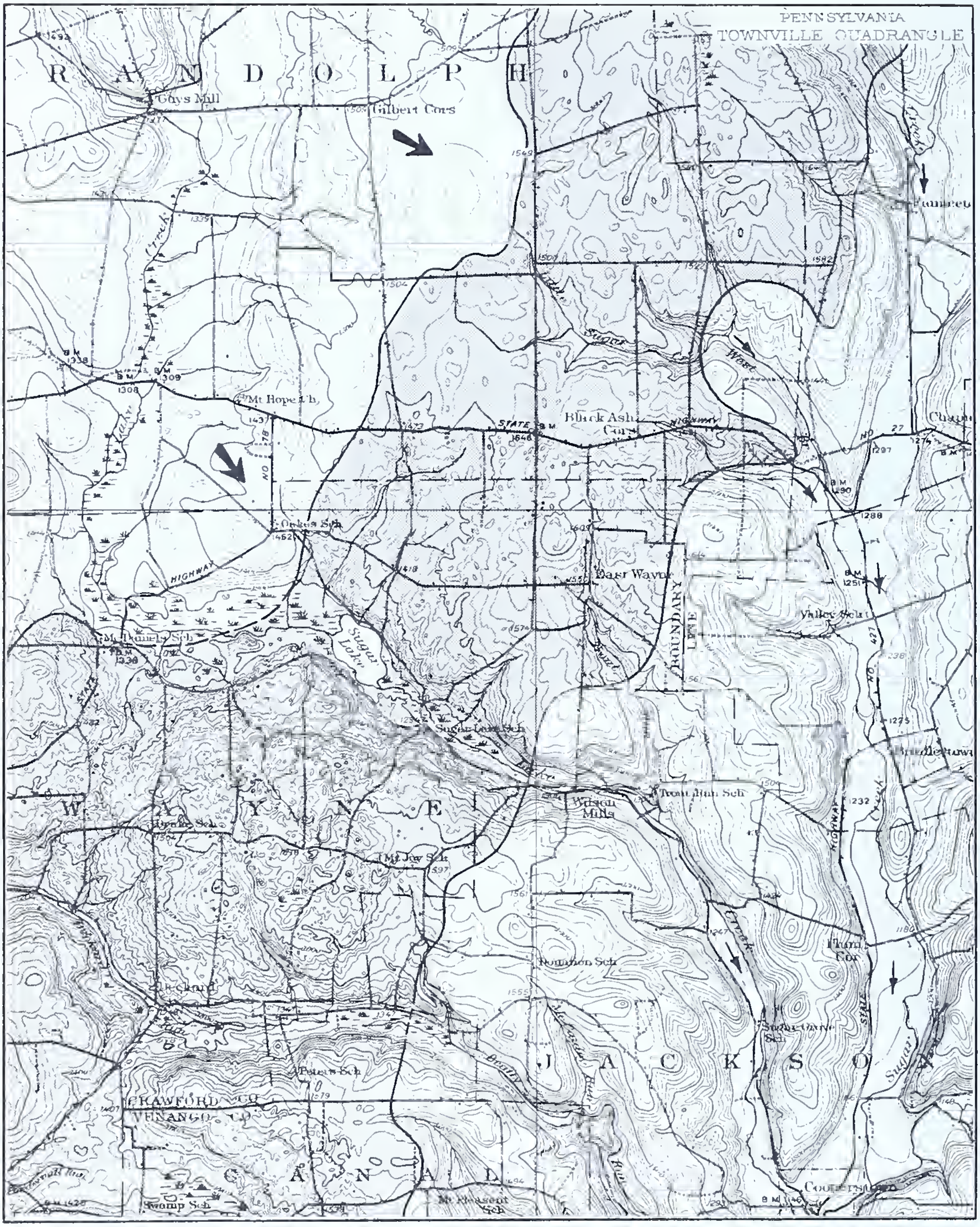

Figure 13. The main Wisconsin end moraine in Crawford County. The shaded area marks the end moraine. Large arrows show the direction in which the ice moved. Small arrows show the drainageways used by meltwaters flowing away from the front of the ice.

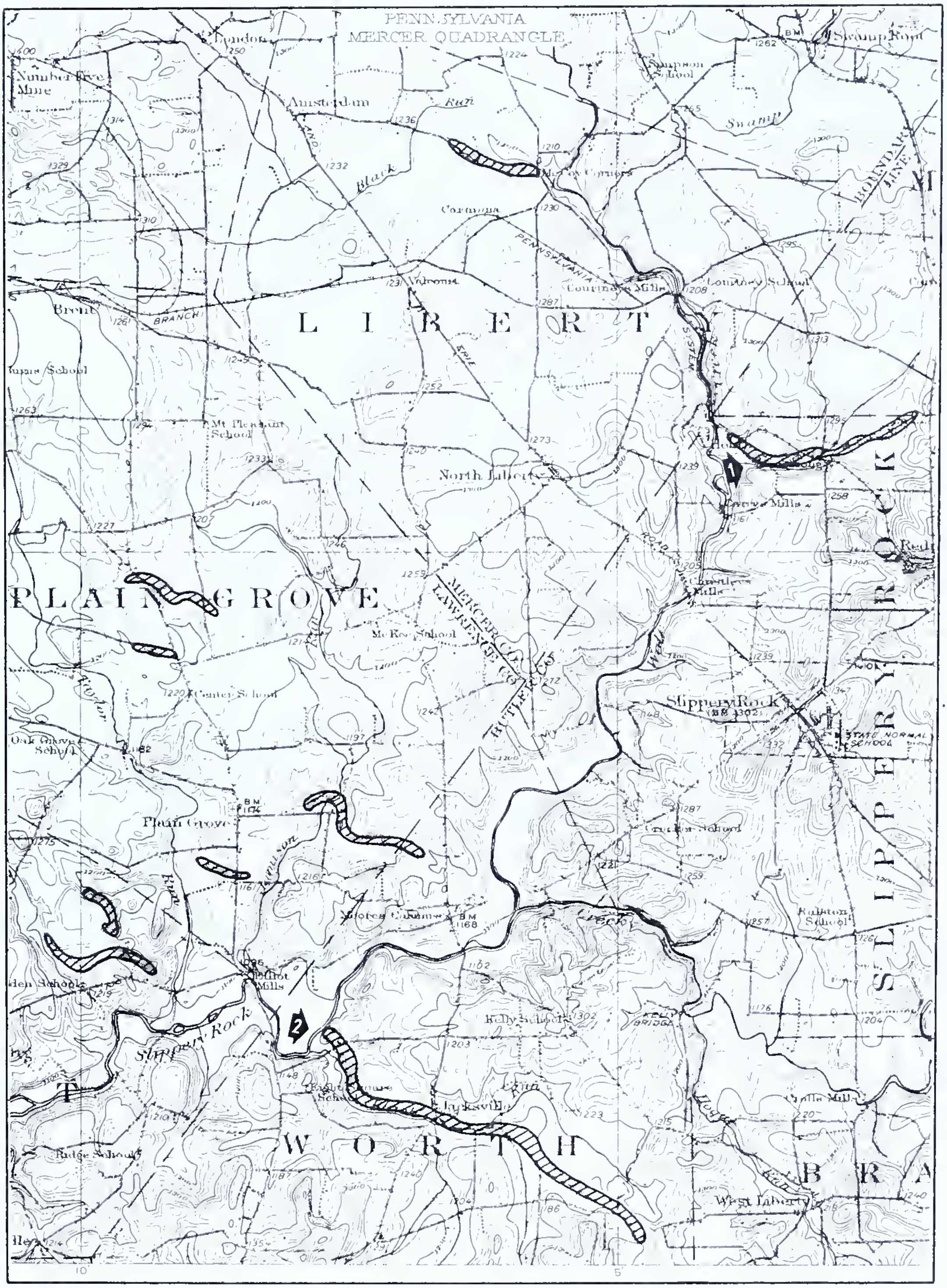

Figure 14. Eskers in northwestern Pennsylvania in Mercer, Lawrence, and Butler Counties. The area shown is in the main Wisconsin end moraine. Note the very irregular nature of the surface and the abundance of small hills.

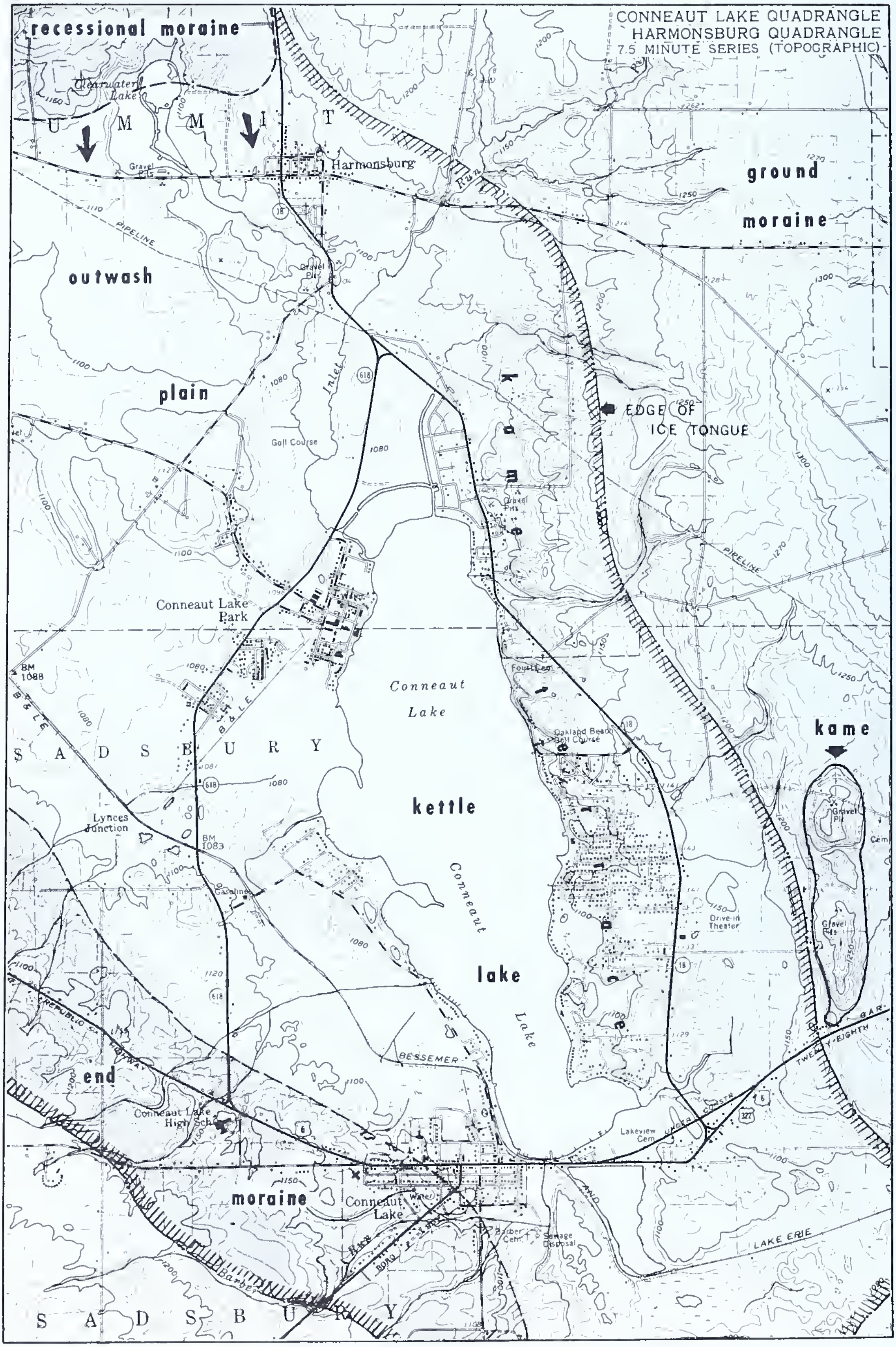

Figure 15. Glacial deposits in the Conneaut Lake area.

The features of the earlier ice sheet include ground moraine and one bold, knobby kame. The ground moraine forms a rather smooth upland surface, typical of the ground moraine areas throughout northwestern Pennsylvania. The kame is the best single illustration of this type of feature in northwestern Pennsylvania. It has been extensively quarried for sand and gravel allowing the visitor an excellent view of the materials which compose a kame. The materials are water-washed sand and gravel which is layered in many different directions. An examination of the pebbles will disclose many different rock types which have been brought from nearby areas as well as from areas many miles away. One can find granites and quartzites from Canada, limestones from New York State, and siltstones and sandstones from Pennsylvania. If you enjoy rock collecting, a visit to this site will enable you to add many varieties of rock to your collections.

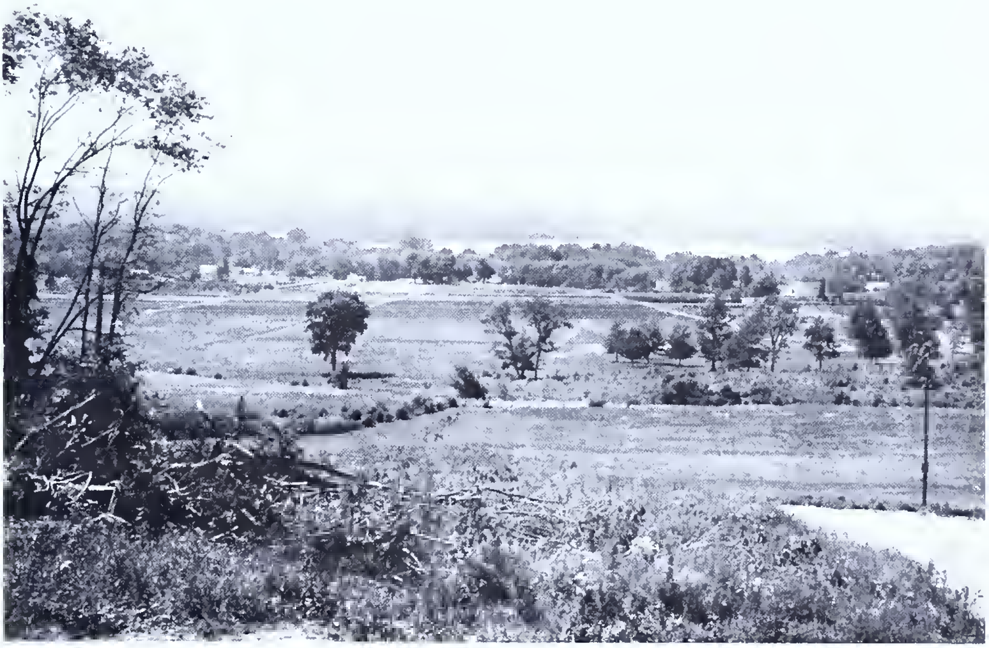

Figure 16. Conneaut Lake as viewed from the large kame east of the lake. Conneaut Lake is a kettle lake formed in the depression left by the melting of a large ice block.

Deposits and features formed by the tongue of ice that moved into the area are no less interesting. Conneaut Lake owes its existence to the ice tongue, because it represents a kettle which has filled with water. When the ice tongue melted away, a large mass of ice remained in the position of the lake while outwash was poured into the valley around the ice block on all sides. By the time the mass of ice melted, outwash was no longer being poured into the valley, so that a water-filled kettle remained. The kame terrace on the east side of the lake was originally a flat-topped terrace formed of this outwash. The surface is no longer flat because it has been dissected by erosion over the years. Northwest of Conneaut Lake Park the broad, gently sloping surface of the land is formed on the top of an outwash plain. This outwash plain was built of materials dumped from streams flowing south from the recessional moraine. The recessional moraine marks the front of the ice tongue which had melted back to a new position, although the ice was still moving forward. The outwash plain is best seen along the road going west out of Harmonsburg. The road travels on the outwash plain and allows a view to the south which shows the plain sloping gradually away. Along the road, several gravel pits have been opened into the outwash plain and an inspection of the materials exposed in these pits will show the types of materials which form an outwash plain. Like the kame, the outwash consists of sands and gravels, but the bedding of the materials is much more uniform than the bedding to be seen in the kame.

Clearwater Lake represents a kettle lake formed in much the same way as Conneaut Lake, though on a smaller scale. This lake was filled through the years with sands and muds nearly to the surface of the water. Swamps spread out over the muds as the water became shallow so that the lake was finally filled with decaying swamp material which gradually became peat. Some years ago, these layers of peat were stripped and sold and the level of the surface was lowered in this way so that the area was again filled with water to become a lake. Peat deposits exist in many parts of northwestern Pennsylvania which have been formed in the same way—by the filling in of kettle lakes.

Clearwater Lake stands on the edge of the recessional moraine. The moraine forms an area of high land which now blocks the valley to the north. The surface through most of this moraine is gently to moderately rolling, but along the south edge of the moraine just west of Clearwater Lake, the surface is made up of a number of long, parallel rolls and swales. The moraine in this area is called a washboard moraine because of its washboard-like surface. Washboard moraines are common in Canada, but not many are seen in the United States. This moraine is best seen by travelling north along the north-south road in the upper left-hand corner of the map which forms a T-intersection with the road from Harmonsburg. After the turn onto the road from Harmonsburg road, watch carefully after passing the farmhouse to see the washboard moraine.

The terminal moraine deposited by this ice tongue was built up on a gently northeast-sloping surface in Sadsbury Township in and west of the town of Conneaut Lake. This moraine is built of till which contains a large amount of clay. Because of the clay content, the material did not build knobby mounds typical of other moraines, but built instead a moderately rolling surface with only scattered low knolls.

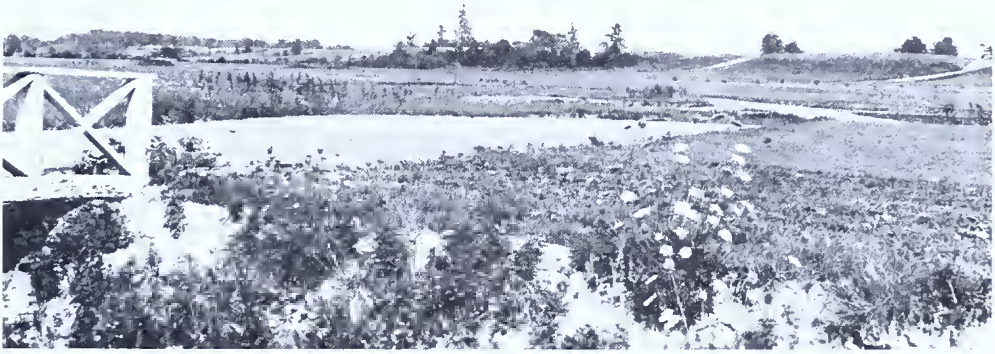

Figure 17. A beach ridge in Erie County. The ridge in the background represents the beach line of Lake Warren, a glacial lake which occupied the Erie Basin, but which stood at a higher level than present Lake Erie. The flat land in the foreground represents the old lake floor. At least three of these ridges can be found on the Erie plain, representing the margins of three lakes which occupied the Erie Basin prior to the formation of present Lake Erie. All three of these lakes existed about 10,000 to 11,000 years ago.

One cannot leave northwestern Pennsylvania without noting one other feature which, though not the direct result of glaciation, was caused by the presence of the glaciers to the north of the State. As the ice front melted back out of Pennsylvania, the drainage of the whole area, which was flowing north prior to the glaciation was dammed by the retreating ice front. This caused waters to build up in the Erie basin to levels higher than the present level of Lake Erie. As you drive north toward Erie, you pass through another bold, knobby end moraine which parallels the southern shore of Lake Erie and then pass from this onto a broad, flat, terraced plain. While driving across this plain, you are driving on the old lake beds of these earlier, higher levels of Lake Erie. At least three different levels of land surface are present each representing a different level of the former lakes. It is these sandy lake beds which support the bulk of Erie County's famous grape vineyards.

As you travel throughout northwestern Pennsylvania, keep in mind that your route is carrying you over the deposits of the great Ice Age and that the scenery you see is largely the result of the glaciations. Note how the character of the land controls the distribution of agriculture, road systems, and communities, and you will see to some extent, the ways in which glaciation has controlled the development of the region.

NORTHEASTERN PENNSYLVANIA

The glacial deposits of northeastern Pennsylvania are known in less detail than those of northwestern Pennsylvania. Our knowledge of the Ice Age history in this area is likewise less complete. We know that ice advanced during Illinoian time and covered a large part of eastern and northeastern Pennsylvania. The outer limit of the advance is shown on the map of Pennsylvania (Figure 11). The Wisconsin ice invaded and covered an area nearly as large as that covered by the Illinoian ice. The borders of the Wisconsin advance are also shown on the map of Pennsylvania.

All of this area is covered with deposits of the glaciers. Lakes, swamps, and kames, all the product of glaciation, are abundant. Outwash poured into the drainageways of the Susquehanna and Delaware Rivers. These river systems contain terraces today which are built of this outwash. Particularly notable are the terraces built along the lower part of the Delaware River in Pennsylvania. It is upon these terraces that much of the city of Philadelphia has been built. The flat floor of the Wyoming Valley, upon which the cities of Wilkes-Barre, Kingston, and Forty Fort have been built, represents the surface on both outwash and lake deposits. Layers of such sediments are as thick as 300 feet in some parts of the Wyoming Valley.

A long continuous end moraine was built along the outer edge of the Wisconsin ice sheet. While the course of this end moraine can be traced continuously from Bangor to Coudersport, it is best developed in the southern one-third of its extent. Figure 19 shows a portion of this end moraine on the Pocono Plateau near Pocono Pines. The moraine is bold and knobby through this area and contains a number of depressions and kettle lakes. The large arrows on the map show the direction in which the ice moved; the small arrows show the courses taken by meltwater streams flowing away from the front of the ice.

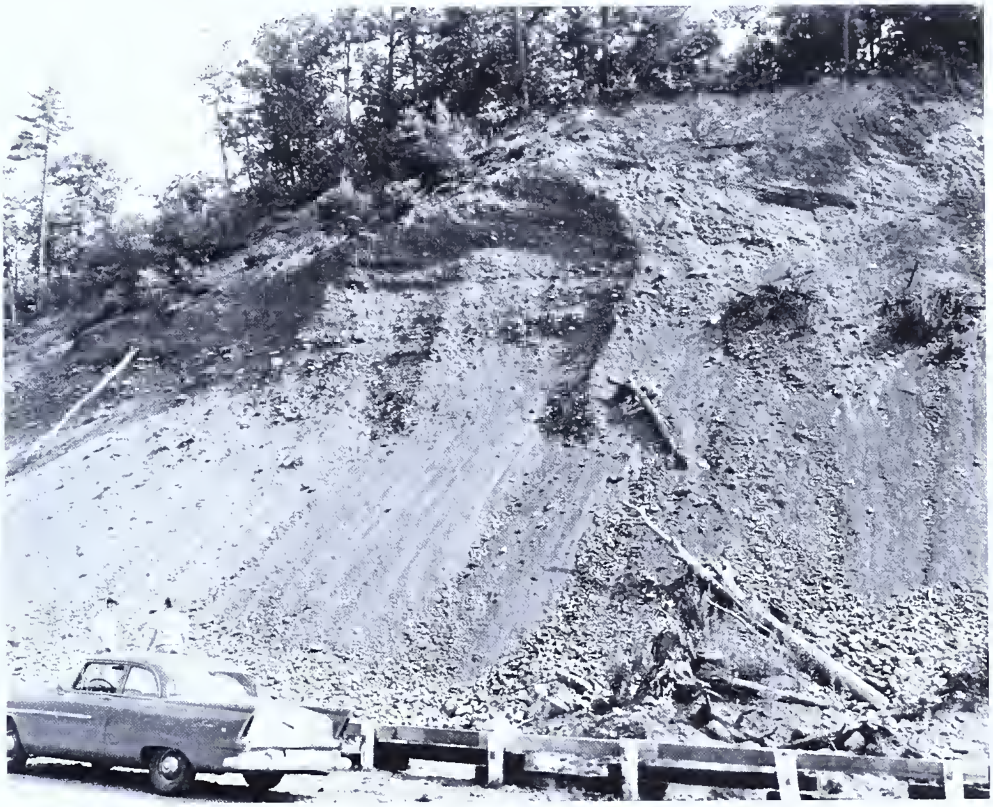

Figure 18. Sands and gravels in a kame near Milford, Pike County. These gravels are exposed in a road cut through a high knob. The bedding of the materials is irregular and is pitched at various angles, typical of kame deposition. The material in this kame is nearly all sand and gravel; in other kames one might expect to find pockets and lenses of silts or even clays, and at times patches of till have been found.

Though the moraine through this area is heavily forested, so that one cannot look out over the landscape to see the rolling, knobby surface, it is possible to observe the influence of the moraine by driving along the road between Little Summit and Long Pond. As the road passes through the moraine it becomes

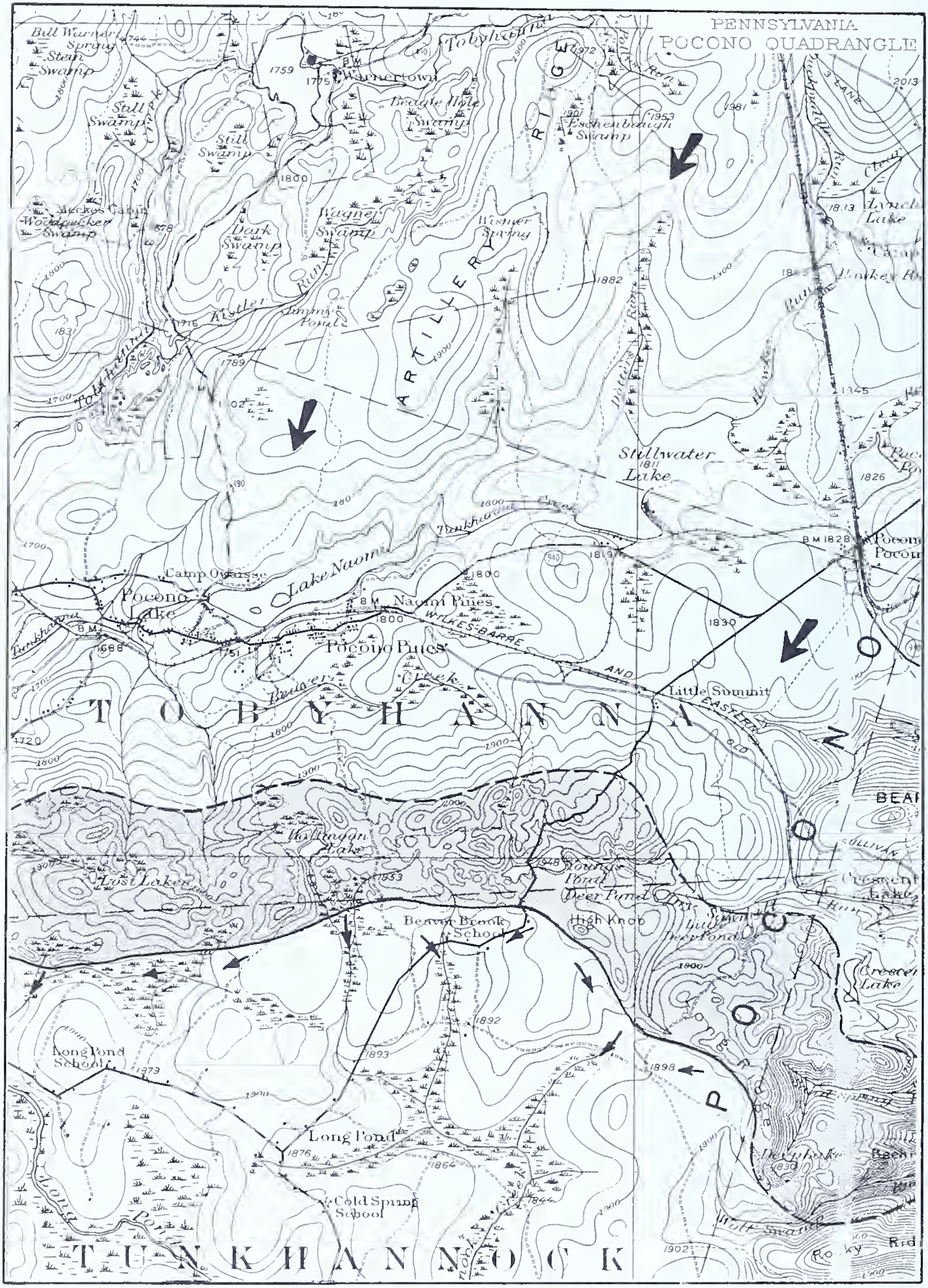

Figure 19. The main Wisconsin end moraine in the Pocono Mountains area in Monroe County. The shaded area marks the end moraine. Numerous kettle lakes exist in the end moraine in this area. Large arrows show the direction in which the ice advanced; small arrows show the drainageways used by meltwaters flowing away from the front of the ice. The area north of the end moraine is covered by ground moraine of very variable thickness.

noticeably twisting and winding and rises and falls as it progresses in and around the morainal knobs.

To the east of the area shown in the map is Big Pocono State Park, established on the top of one of the highest mountains in the Poconos. The road leading up the mountain to the park passes through the end moraine which is indicated by alternations of hill and swale topography along both sides of the road. The highway repeatedly cuts the knobs and exposes the till which composes the end moraine. The till in this area is sandy so that it might be confused with deposits of sand and gravel. But a close examination of the cuts reveals that the material is quite mixed and contains a fair quantity of silt and some clay. These cuts afford the visitor a chance to collect a great variety of rock types contained in the pebbles and cobbles of the till. Similar cuts in till can be seen along the rim road in the park atop Big Pocono Mountain. The presence of till at the top of the mountain tells us that the glaciers reached up to this point, and since the difference in elevation between the top of the mountain and the valley below is 1100 feet, the ice in this area must have been at least that thick.

The great abundance of glacially formed lakes in the Pocono area have helped to make it one of the East's most noted resort areas. The filling of numerous of these lakes by peat has given parts of eastern Pennsylvania an industry they otherwise would not have had.

THE IMPORTANCE OF GLACIATION TO PENNSYLVANIA

The glaciations of the Ice Age have greatly affected many parts of our country and Canada. The economic and political importance of the Great Lakes, created by glacial action, was told in previous sections of this booklet. This is only one of the ways the glaciers have directed the course of events in our state and country. Nearly all of the good soils of the northern states were formed on glacial deposits. The great corn and wheat crops of the midwest are planted on rich soils formed of ground moraine or on wind-blown silt derived from glacial materials. Northwestern Pennsylvania has become one of our State's more important agriculture and dairying areas because of its rich, glacial soils. The importance of the Erie County lake beds to grape production has been noted earlier.

Glacial deposits yield products of importance to the State's economy. Nearly all of the sand and gravel, and all of the peat produced every year in Pennsylvania exist because of glaciation. Large amounts of water pumped from the ground are available only because they have been stored in the glacial deposits. Wells at Meadville and Wilkes-Barre can yield as much as 2000 gallons of water per minute. It's hard to picture flows like this, but perhaps you can get some idea of these quantities if you realize that the flow from one of these wells could fill a bathtub in one second.

The scenery of the glacial areas, the many lakes and unusual streams have attracted visitors to the State. Noted Pennsylvania landmarks such as the Grand Canyon of Pennsylvania, Hickory Run boulder field, Split Rock, and the Archibald Pothole are all related to glaciation, not to mention Lake Erie and Conneaut Lake.

Special thought of the glacial deposits must be taken every time a road, or a building, or a dam is built upon them. Glacial sediments are not hard like bedrock because they have not been hardened or cemented by time or pressure. This means that they can be dug with a shovel or a bulldozer so that they are easily moved around, but they do not have the strength to hold up a large structure unless special precautions are taken. Some glacial deposits become sticky or soupy when wet, creating special drainage problems.

For all these reasons—for the scenery glaciation created; for the soil and mineral resources provided by the glacial deposits; for the influence the glaciers have had on our political boundaries, our water supply, and our river systems; and for the engineering problems they create—it should be clear that the glaciations of the past are important to us and are consequently a story that we should know something about.

TOPOGRAPHIC MAPS ILLUSTRATING PENNSYLVANIA'S GLACIAL FEATURES

Feature	U. S. Geological Survey Topographic Quadrangle*
END MORAINE	Sandy Lake 7½′. Pocono 15′, see Figure 19. Bangor 15′, just north of Bangor along the base of the mountain.
VALLEY TRAIN	Brodheadsville 7½′, Pohopoco Creek valley floor. Pittston 7½′, Wyoming Valley floor. Milford 15′, along Delaware River valley as terraces. Beaver Falls 7½′, terraces along Beaver River especially at Koppel.
LAKE DEPOSITS	Cambridge Springs 15′, flat valley bottom north of Cambridge Springs is on lake deposits. Swanville 7½′, beach ridges just above 700 and 750 foot contour lines; lowest is beach of ancient Lake Arkona; highest is beach of Lake Maumee.
KAMES	Conneaut Lake 7½′, east of Conneaut Lake; east of West Vernon; and west of Stony Point—north of Jackson Run. Milford 15′, just south of Milford at the valley edge, base marked by 500-foot contour line.
ESKERS	Mercer 15′, see Figure 8.
KETTLE LAKE	Conneaut and Harmonsburg 7½′ quadrangles, Conneaut Lake and Clearwater Lake are kettle lakes, see text. Cambridge Springs 15′, Edinboro Lake is a kettle lake. Brodheadsville 7½′, small lakes in valley of Pohopco Creek are kettle lakes.
DRUMLINS	Wattsburg 7½′, spoon-shaped hills are drumlins. Note also lineated topography; this has been called in other areas "corrugated topography" because of its resemblance to corrugated cardboard.

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* To order topographic maps, write to the Department of Environmental Resources, Bureau of Topographic and Geological Surveys, Harrisburg, Pennsylvania 17120, for free brochure entitled "Index to Topographic Mapping in Pennsylvania."

ADDITIONAL READING ON GLACIERS

POPULAR READING

Glaciers, by Robert P. Sharp. University of Oregon Press, Eugene, Oregon, 1961. An easily read discussion of glaciers, beautifully illustrated to provide the reader with a visual image of the character and variation of these ice bodies.

The World of Ice, by James L. Dyson. Alfred A. Knopf, Inc., New York, 1962. A summary of the occurrence of ice on the earth and the many forms that it assumes. Considers also the ice of the Ice Age and the impact that the coming and going of the glaciers has had on man. Written in a very enjoyable style and within the grasp of the average person.

The World We Live In, by Life Magazine Staff. Simon and Schuster, New York, special edition for young readers, 1956. Part X on the Arctic Barrens shows modern glaciated areas.

Modern Earth Science, by W. L. Ramsey and R. E. Burckley. Holt, Rinehart, and Winston, Inc., 1961. Student textbook covers all phases of earth science including a complete chapter on glaciers.

Earth Science, by G. L. Fletcher and C. W. Wolfe. Heath, Boston, 4th edition, 1959. A textbook for students which covers all topics of earth science including a chapter on glaciation.

ADVANCED READING

Glacial and Pleistocene Geology, by Richard F. Flint. Wiley, New York, 1957. A college textbook and sourcebook on all phases of glaciers and glaciation.

Geology of the Great Lakes, by Jack L. Hough. University of Illinois Press, Urbana, Illinois, 1958. The last word on the history and evolution of the Great Lakes.

OTHER BOOKLETS IN THE PENNSYLVANIA GEOLOGICAL SURVEY EDUCATIONAL SERIES

ES 1	Common Rocks and Minerals of Pennsylvania
ES 2	Common Fossils of Pennsylvania
ES 3	Ground Water
ES 4	Pennsylvania Geology Summarized
ES 5	Geology and the Gettysburg Campaign
ES 7	Coal in Pennsylvania
ES 8	Geology of Pennsylvania's Oil and Gas

BOOKLETS PUBLISHED BY THE PENNSYLVANIA GEOLOGICAL SURVEY ON THE GLACIATION OF PENNSYLVANIA

Bulletin G-7. Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania, by Frank Leverett. 1934. ($1.00*.)

Bulletin G-9. The geomorphology of the Wyoming-Lackawanna region, Pennsylvania, by H. I. Itter. 1938. ($0.70*.)

Bulletin G-10. Recent geological history of the Delaware Valley below the Water Gap, by Freeman Ward. 1938. ($0.55*.)

Bulletin G-23. Pleistocene terraces of the Susquehanna River, by L. S. Peltier. 1949. ($2.35*.)

Bulletin G-32. Glacial geology of northwestern Pennsylvania, by V. C. Shepps; G. W. White; J. B. Droste; and R. F. Sitler. 1959. ($3.75*.)

Bulletin G-55. Pleistocene Stratigraphy of northwestern Pennsylvania, by G. W. White, S. M. Totten, and D. L. Gross. 1969. ($1.00*.)

Bulletin G-57. Surficial geology of the Stroudsburg quadrangle, Pennsylvania-New Jersey, by J. B. Epstein. 1969. ($2.75.*)

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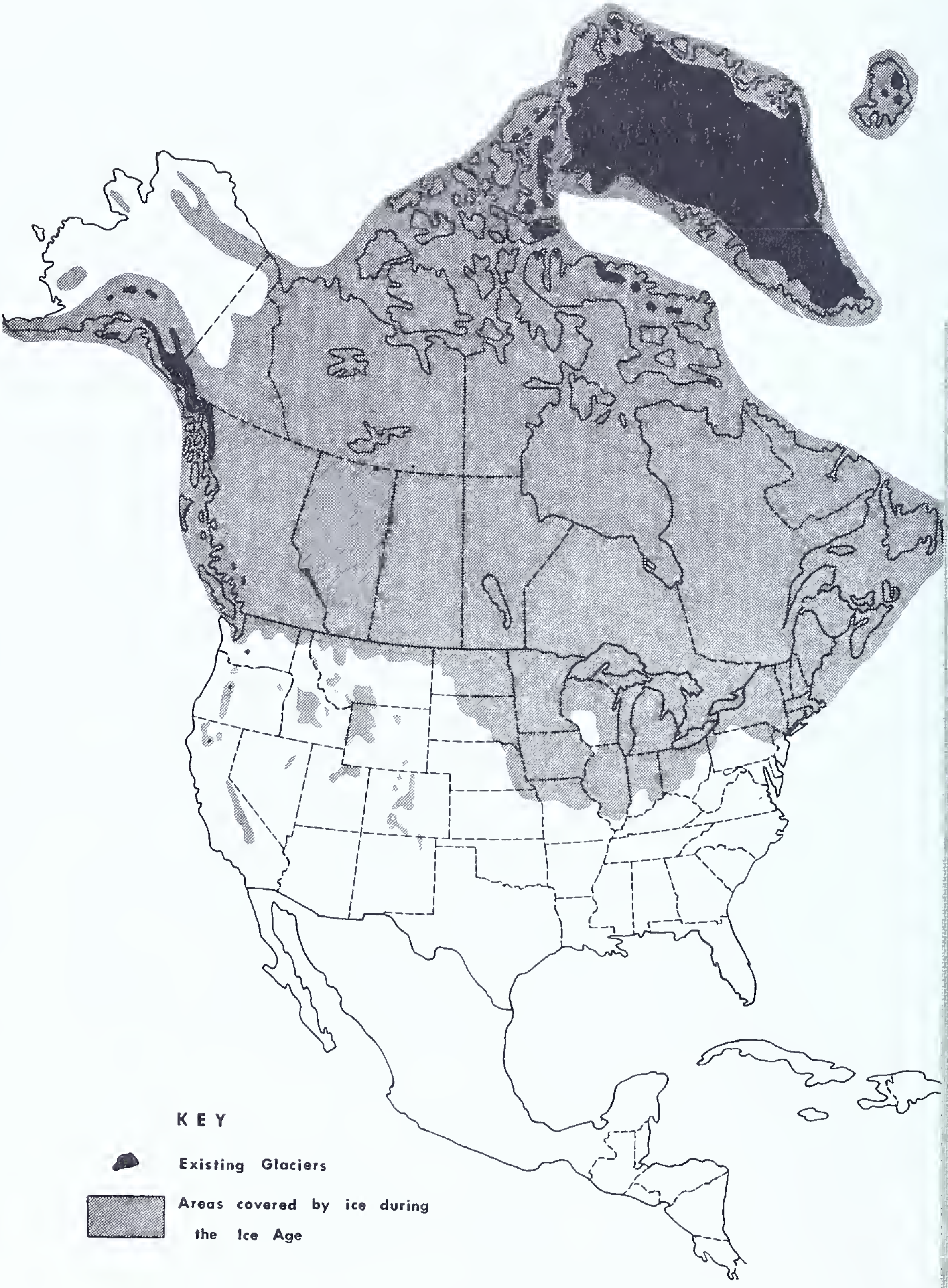
KEY
Existing Glaciers
Areas covered by ice during the Ice Age